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CALIBRATION LABORATORIES

NVLAP LAB CODE 105002-0

SANDIA NATIONAL LABORATORIES

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DIMENSIONAL

NVLAP Code: 20/D01
Angular

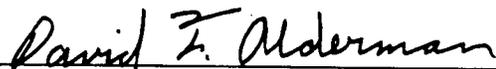
<i>Range</i>	<i>Best Uncertainty (\pm) in percent^{note 1}</i>	<i>Remarks</i>
Angle Blocks	0.60 arc second	Standard Sizes, 1 arc second to 45°
Optical Squares	0.46 arc second	
True Squares	0.28 arc second	

NVLAP Code: 20/D03
Gage Blocks

<i>Range</i>	<i>Best Uncertainty (\pm) in percent^{note 1,8}</i>	<i>Remarks</i>
to 100 mm (4 in)	30 nm + 0.14 L	Interferometry with Historical Analysis
to 100 mm (4 in)	34 nm + 0.33 L	Interferometry, single wiring

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< 1 mm (.04 in)	41 nm	Mechanical Comparison to Masters ^{note 2,3,4}
1 to 100 mm (.04 to 4 in)	35 nm + 0.59 L	Mechanical Comparison to Masters ^{note 2,3,4}
125 to 500 mm (5 to 20 in)	127 nm + 0.30 L	Mechanical Comparison to Masters ^{note 2,3,4}

DC/LOW FREQUENCY

NVLAP Code: 20/E01
Voltage Converters

Best Uncertainty (±) in ppm^{note 1}

Frequency in Hertz

<i>Range</i>	<i>10</i>	<i>100</i>	<i>1 k</i>	<i>20 k</i>	<i>50 k</i>	<i>100 k</i>	<i>200 k</i>	<i>500 k</i>	<i>1 M</i>
1 V	102	20	23	17	26	42	71	73	75
2 V	101	18	17	21	27	42	72	71	73
3 V	102	16	18	17	27	42	71	73	75
4 V	101	17	17	19	30	42	71	71	72
6 V	101	16	16	17	27	41	72	74	76
10 V	101	16	18	18	27	41	72	73	74
12 V	101	18	18	16	27	42	72	72	73

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20 V	104	19	16	17	30	41	72	76	78
30 V	102	17	16	16	27	42	71	76	77
40 V	101	17	16	19	27	41	73	76	77
60 V	101	23	16	17	27	42	71	71	74
100 V	101	19	16	17	28	43	73	75	75
120 V	102	22	21	22	31	52			
200 V	101	23	22	24	32	51			
300 V	103	29	25	25	34	56			
400 V	102	21	22	22	32	59			
600 V	102	23	22	21	33	57			
1000 V	104	31	29	31	43	69			

NVLAP Code: 20/E01
AC Current Shunts

<i>Range</i>	<i>Frequency</i>	<i>Best Uncertainty (\pm) in percent^{note 1}</i>
10 mA	50 kHz	0.010
25 mA	50 kHz	0.010
50 mA	50 kHz	0.010
100 mA	50 kHz	0.014

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250 mA	50 kHz	0.010
500 mA	50 kHz	0.011
1 A	50 kHz	0.011
1 A	100 kHz	0.014
2.5 A	50 kHz	0.011
5 A	50 Hz	0.009
5 A	60 Hz	0.009
5 A	50 kHz	0.011
10 A	50 kHz	0.017
20 A	50 Hz	0.013
20 A	400 Hz	0.013
20 A	1 kHz	0.013
20 A	50 kHz	0.017

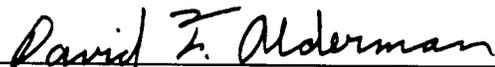
NVLAP Code: 20/E03

Capacitance Dividers - Pulsed High-Voltage Condition

<i>Range</i>	<i>Best Uncertainty (\pm) in percent^{note 1}</i>	<i>Remarks</i>
1 to 350 kV	2.0	1 to 30 μ s Pulse

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NVLAP Code: 20/E05

DC Resistance

<i>Range in ohms</i>	<i>Best Uncertainty (\pm) in ppm^{note 1}</i>	<i>Remarks</i>
0.0001 to 0.001	11	Low Resistance
0.001 to 0.01	4	Low Resistance
0.01 to 0.1	2.5	Low Resistance
0.1 to 1	2	Low Resistance
1	0.057	Thomas
1 to 10	1	
10 to 10 ⁴	0.5	
10 k	0.15	SR104
10 ⁵	2	
10 ⁶	3	
10 ⁷	5	
10 ⁸	10	
10 ⁸	240	with Teraohmeter

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10^9	330	with Teraohmeter
10^{10}	470	with Teraohmeter
10^{11}	670	with Teraohmeter
10^{12}	1400	with Teraohmeter
10^{13}	2000	with Teraohmeter
10^{14}	3300	with Teraohmeter
10^{15}	6700	with Teraohmeter
10^{16}	7.0%	with Teraohmeter
Special Resisters		
2 and 5	0.5	Reichsanstalt
25 and 100	0.15	Tinsley
28.5	0.5	NBS
Shunts		
100 mA to 1000 A	2.5	

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NVLAP Code: 20/E06

DC Voltage

<i>Range</i>	<i>Best Uncertainty (\pm) in ppm^{note 1}</i>	<i>Remarks</i>
1, 1.018 V	0.14	Josephson Array System
10.0 V	0.017	Josephson Array System
1.018 V	0.21	Standard Cell System
1.0 to 10.0 V	0.26	Zener Ref. System

Voltage dividers - Potentiometer combination

1.5 V to 1500 V	2.5	Intermediate System
x1.0 range to 1.05 V	0.5 of reading +0.1 μ V	Potentiometer only, k=3
x1.0 range above 1.05 V	1.0 of reading +0.1 μ V	Potentiometer only, k=3
x0.1 range	1.5 of reading +0.01 μ V	Potentiometer only, k=3
x0.01 range	2.5 of reading +0.005 μ V	Potentiometer only, k=3

High Voltage

to 100 kV	106	200 kV system
100 kV to 200 kV	140	200 kV system

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to 10 kV	0.2%	10 kV system
Ratio/Bridges		
1:1 to 1:100,000	0.5 x 10 ⁷ (ratio)	For ratio based on 20 step first dial (k=3). For bridges, uncertainty combines ratio and resistance uncertainties

NVLAP Code: 20/E08
Inductive Dividers

<i>Range</i>	<i>Best Uncertainty (±) in ppm^{note 1}</i>	<i>Remarks</i>
15, 35 and 100 V	55	@ 60, 1 k and 10 kHz

NVLAP Code: 20/E10
LF Capacitance

<i>Range</i>	<i>Best Uncertainty (±) in ppm^{note 1}</i>	<i>Remarks</i>
0.01 to 1000 pF	5	@ 1 kHz

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NVLAP Code: 20/E11
LF Inductance

Best Uncertainty (\pm) in percent^{note 1}

<i>Range</i>	<i>Frequency in Hz</i>		
	<i>100</i>	<i>1 k</i>	<i>10 k</i>
10 μ H	1.10	0.20	0.20
20 μ H	0.50	0.20	0.20
50 μ H	0.20	0.20	0.20
100 μ H	0.10	0.10	0.10
200 μ H	0.10	0.10	0.10
500 μ H	0.02	0.02	0.05
1 mH	0.02	0.02	0.06
2 mH	0.03	0.03	0.06
5 mH	0.03	0.03	0.06
10 mH	0.02	0.02	0.05
20 mH	0.02	0.02	0.05
50 mH	0.02	0.02	0.05
100 mH	0.02	0.02	0.05

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200 mH	0.02	0.02
500 mH	0.02	0.02
1 H	0.02	0.05
2 H	0.02	0.05
5 H	0.02	0.10
10 H	0.02	0.20

NVLAP Code: 20/E18

Resistive Dividers - Pulsed High-Voltage Condition

<i>Range</i>	<i>Best Uncertainty (\pm) in percent^{note 1}</i>	<i>Remarks</i>
1 to 350 kV	1.0	1 to 30 μ s Pulse

TIME AND FREQUENCY

NVLAP Code: 20/F01

Frequency Dissemination

<i>Range</i>	<i>Best Uncertainty (\pm)^{note 1}</i>	<i>Remarks</i>
0.1 MHz	1 part in 10^{12}	
1 MHz	1 part in 10^{12}	
5 MHz	1 part in 10^{12}	
10 MHz	1 part in 10^{12}	

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IONIZING RADIATION

NVLAP Code: 20/I04

Radioactive Sources

<i>Range</i>	<i>Best Uncertainty (\pm)^{note 1}</i>	<i>Remarks</i>
Alpha Emission Rate		
1 to 2×10^5 /s into 2π	1.6 %	
Beta Emission Rate		
50 to 5000 /s into 2π	5.0 %	
Alpha Energy		
3 to 8 MeV	30 keV	

MECHANICAL

NVLAP Code: 20/M06

Force

<i>Range</i>	<i>Best Uncertainty (\pm) in percent^{note 1, 2, 6}</i>	<i>Remarks</i>
100 to 1,000	0.0052	Primary Standard (Deadweight)
1,000 to 100,000	0.016	Secondary Standards (Proving Rings)
50 to 30,000	0.075	Secondary Standards (Load Cells) ^{note 7}

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RF MICROWAVE

NVLAP Code: 20/R05
HF Capacitance

Best Uncertainty (\pm) in percent^{note 1}

Frequency in Hz

<i>Range in pF</i>	<i>100</i>	<i>1 k</i>	<i>10 k</i>	<i>100 k</i>	<i>1 M</i>
0.01		0.20		1.3	
0.1		0.05		1.3	
1		0.02		0.04	
10		0.01		0.02	
100		0.01		0.01	
1000		0.01		0.03	
1		0.02		0.2	0.30
2		0.02		0.35	0.60
5		0.02		0.22	0.26
10		0.10		0.14	0.15
20		0.10		0.13	0.11

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50				0.03	0.02
100				0.02	0.02
200				0.01	0.01
500				0.02	0.01
1000				0.02	0.03
10		0.0001			
100		0.0001			
1	0.01	0.01	0.01	0.01	0.01
10	0.01	0.01	0.01	0.01	0.01
100	0.01	0.01	0.01	0.01	0.01
1000	0.01	0.01	0.01	0.01	0.01

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NVLAP Code: 20/R06
HF Inductance

Best Uncertainty (\pm) in percent^{note 1}

Frequency in Hz

<i>Range</i>	<i>10 k</i>	<i>100 k</i>	<i>1 M</i>	<i>10 M</i>
0.1 μ H		2.19	4.00	
0.2 μ H		2.03	2.03	
0.5 μ H		0.80	1.20	
1.0 μ H		0.56	0.92	
2.0 μ H		0.31	0.73	
5.0 μ H		0.25	0.68	
10 μ H		0.39	0.63	
25 μ H		0.32	0.16	
50 μ H		0.26	0.12	
100 μ H		0.24	0.11	
250 μ H		0.32	0.16	
500 μ H		0.26	0.09	
1 mH		0.24		

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2.5 mH				0.25
5 mH				0.24
10 mH				0.29
25 mH				0.25
0.25 μ H	1.2	1.4	1.7	0.8
1 μ H	0.4	0.5	0.9	0.6
10 μ H	0.4	0.4	0.6	0.1
100 μ H	0.2	0.2	0.2	

NVLAP Code: 20/R10
Q Standards

<i>Range</i>	<i>Best Uncertainty (\pm) in percent^{note 1}</i>			<i>Remarks</i>
Selected values from 95 to 607	1.2 to 4.5 dependent on Q value and frequency			frequency range 50 kHz to 45 MHz

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NVLAP Code: 20/R11
RF-DC Voltage Converter
High Frequency TVC

Best Uncertainty (\pm) in percent^{note 1}

<i>Range</i>	<i>Frequency in Hz</i>				
	<i>1 M</i>	<i>10 M</i>	<i>30 M</i>	<i>50 M</i>	<i>100 M</i>
0.5 V	0.06	0.11	0.21	0.51	1.1
1 V	0.06	0.11	0.21	0.51	1.1
2 V	0.06	0.11	0.21	0.51	1.1
2.5 V	0.06	0.11	0.21	0.51	1.1
3 V	0.06	0.11	0.21	0.51	1.1
5 V	0.06	0.11	0.21		1.1
10 V	0.06	0.11	0.21		1.1
20 V	0.06	0.11	0.21		1.1
50 V	0.06	0.11	0.22		1.2
100 V	0.06	0.11	0.27		1.5
200 V	0.06	0.12	0.21		1.1

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RF TVC

Best Uncertainty (±) in percent^{note 1}

Frequency in Hz

<i>Range</i>	<i>300 M</i>	<i>600 M</i>	<i>700 M</i>	<i>800 M</i>	<i>900 M</i>	<i>1000 M</i>
1 V	1.3	1.3	1.3	1.3	1.3	1.3
2.4 V	1.3	1.3	1.3	1.3	1.3	1.3
7 V	1.3	1.3	1.3	1.3	1.3	1.3

Micropotentiometers

Best Uncertainty (±) in percent^{note 1}

Frequency in Hz

<i>Range</i>	<i>30 M</i>	<i>100 M</i>	<i>300 M</i>	<i>600 M</i>	<i>900 M</i>
0.1 mV	2.32	3.56	3.36	5.10	5.10
0.2 mV	0.54	1.04	1.02	1.35	1.42
0.4 mV	2.34	3.44	3.18	5.10	5.10
0.9 mV	0.54	1.04	1.05	1.35	1.44
1 mV	2.24	3.33	3.21	5.10	5.10

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1.5 mV	0.59	1.02	1.02	1.33	1.33
4 mV	0.53	1.07	1.21	1.38	1.39
5 mV	2.24	3.16	3.17	5.10	5.10
10 mV	2.27	3.19	3.16	5.10	5.10
11 mV	2.25	3.17	3.58	5.10	5.10
25 mV	0.48	0.97	0.97	1.28	1.30
28.5 mV	2.52	3.49	3.95	5.10	
102 mV	0.53	0.99	1.08	1.30	1.28
150 mV	0.43	0.99	1.06	1.32	1.28
320 mV	2.24	3.23	3.18	5.10	5.10
330 mV	0.45	1.01	0.98	1.38	1.29

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RF/Microwave Bolometer Units

Expanded Uncertainties^{note 1,2,3} on Effective Efficiency & Calibration Factor of HP bolometric power sensors.

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-12000	12000-18000
N	Calibration Factor	0.9 to 1	0.004-0.006	0.004-0.006	0.005-0.007	0.006-0.008
APC-3.5	Calibration Factor	0.9 to 1	-----	0.007-0.009	0.009-0.010	0.010-0.011
N	Effective Efficiency	0.9 to 1	0.004-0.005	0.004-0.005	0.005-0.006	0.006-0.008
APC-3.5	Effective Efficiency	0.9 to 1	-----	0.007-0.008	0.008-0.009	0.009-0.010

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RF/Microwave Attenuators

Reflection Coefficient (or Scattering Parameter S_{ii})

A. Dual 6-Port Network Analyzer Certification Uncertainties *note 2,3,4*

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-12000	12000-18000
GR-900	$ S_{ii} $	0 to 1	0.002-0.009	0.002-0.015	-----	-----
N	$ S_{ii} $	0 to 1	0.002-0.008	0.002-0.027	0.006-0.018	0.006-0.030
APC-7	$ S_{ii} $	0 to 1	0.002-0.006	0.002-0.009	0.003-0.018	0.005-0.015
APC-3.5	$ S_{ii} $	0 to 1	0.002-0.012	0.002-0.015	0.005-0.019	0.012-0.050
GR-900	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	0.120-180.0	0.019-180.0	-----	-----
N	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	0.360-180.0	0.300-180.0	0.600-180.0	0.800-180.0
APC-7	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	0.012-180.0	0.200-180.0	0.540-180.0	0.525-180.0
APC-3.5	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	0.360-180.0	0.240-180.0	0.540-180.0	0.560-180.0

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B. HP8510 Vector Network Analyzer Uncertainties

1. Expanded Uncertainties ^{note 1,2,3} on one or two-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-12000	12000-18000
N	$ S_{ii} $	0 to 1	0.001-0.003	0.001-0.009	0.004-0.009	0.004-0.021
APC-7	$ S_{ii} $	0 to 1	0.001-0.007	0.001-0.003	0.003-0.007	0.001-0.004
APC-3.5	$ S_{ii} $	0 to 1	0.001-0.007	0.004-0.020	0.004-0.020	0.004-0.020
N	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	0.05-180	0.36-180	1.43-180	1.34-180
APC-7	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	0.15-180	0.16-180	0.33-180	0.38-180
APC-3.5	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	0.53-180	0.33-180	0.35-180	0.33-180

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2. Certification Uncertainties ^{note 2,3,4} on three-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-12000	12000-18000
N, APC-7, APC-3.5	$ S_{ii} $	0 to 0.3	0.011 - 0.075	0.011 - 0.075	0.03 - 0.09	0.050 - 0.092
N, APC-7, APC-3.5	$ \Gamma_{ge} $	0 to 0.3	0.011 - 0.080	0.012 - 0.080	0.030 - 0.084	0.071 - 0.119

C. HP8753 Vector Network Analyzer Certification Uncertainties ^{note 2,3,4}

1. One or two-port devices

Connector Type	Quantity	Quantity Range	25-1000	1000-3000
N	$ S_{ii} $	0 to 1	0.001-0.009	0.003-0.016
APC-7	$ S_{ii} $	0 to 1	0.002-0.04	0.002-0.004
APC-3.5	$ S_{ii} $	0 to 1	0.006-0.02	0.006-0.035
N	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	0.2-70	1-180
APC-7	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	0.3-180	0.2-25
APC-3.5	$\text{Arg}(S_{ii})$	$0 < S_{ii} < 1$ -180 to +180 deg	1-180	1.6-180

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2. Three-port devices

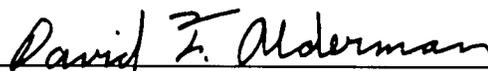
Connector Type	Quantity	Quantity Range	25-1000 (MHz)
N, APC-7-APC-3.5	$ S_{ii} $	0 to 0.3	0.011 - 0.020
N, APC-7-APC-3.5	$ \Gamma_{gc} $	0 to 0.3	0.01 - 0.03

D. Weinschel VM-4B Certification Uncertainties note 2,3,4

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			10-2000	2000-8000	8000-12000	12000-18000
N	$ S_{ii} $	0 to 1	0.025-0.080	0.031-0.085	0.040-0.090	0.046-0.112
APC-7	$ S_{ii} $	0 to 1	0.011-0.075	0.015-0.080	0.030-0.085	0.036-0.106
BNC	$ S_{ii} $	0 to 1	0.026-0.060 ^{note 5}	-----	-----	-----

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Attenuation (or Scattering Parameter S_{ij})

A. Dual 6-Port Network Analyzer Certification Uncertainties ^{note 2,3,4}

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-12000	12000-18000
GR-900	$ S_{ij} $	0 to 60 dB	0.012-0.390	0.015-0.410	-----	-----
N	$ S_{ij} $	0 to 60 dB	0.012-0.390	0.015-0.410	0.018-0.410	0.021-0.900
APC-7	$ S_{ij} $	0 to 60 dB	0.012-0.390	0.015-0.410	0.020-0.410	0.021-0.900
APC-3.5	$ S_{ij} $	0 to 60 dB	0.012-0.150	0.015-0.410	0.020-0.410	0.030-0.90

B. HP8510 Vector Network Analyzer Uncertainties

1. Expanded Uncertainties ^{note 1,2,3} on one or two-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-12000	12000-18000
N	$ S_{ij} $	0 to 60 dB	0.01-0.12	0.02-0.17	0.03-0.25	0.03-0.48
APC-7	$ S_{ij} $	0 to 60 dB	0.01-0.08	0.01-0.13	0.01-0.13	0.01-0.18
APC-3.5	$ S_{ij} $	0 to 60 dB	0.01-0.12	0.02-0.22	0.04-0.25	0.05-0.49

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N	Arg(S_{ij})	$0 < S_{ij} < 60$ dB 0 to 360 deg	0.22-1.19	0.32-1.27	0.36-1.84	0.58-3.46
APC-7	Arg(S_{ij})	$0 < S_{ij} < 60$ dB 0 to 360 deg	0.22-0.73	0.25-1.21	0.41-1.70	0.57-2.85
APC-3.5	Arg(S_{ij})	$0 < S_{ij} < 60$ dB 0 to 360 deg	0.45-0.80	0.35-1.39	0.41-1.94	0.66-3.17

2. Certification Uncertainties ^{note 2,3,4} on three-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-12000	12000-18000
N, APC-7, APC-3.5	{Coupling} (dB)	3-40 dB	0.071 - 0.320	0.110 - 0.500	0.012 - 0.500	0.320 - 0.600
N, APC-7, APC-3.5	{Mainline} (dB)	0 to 8 dB	0.020 - 0.221	0.020 - 0.221	0.020 - 0.221	0.131 - .290
N, APC-7 APC-3.5	{Directivity} (dB)	15-25 dB	0.19 - 9.2	0.53 - 9.2	0.80 - 9.2	1.55 - 9.2
N, APC-7, APC-3.5	{Directivity} (dB)	30-40 dB	1.0 - ∞	2.6 - ∞	5.7 - ∞	7.2 - ∞

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C. HP8753 Vector Network Analyzer Certification Uncertainties^{note 2,3,4}

1. One or two-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)	
			25-1000	1000-3000
N	$ S_{ij} $	0 to 60 dB	0.003-0.5	0.004-1.2
APC-7	$ S_{ij} $	0 to 60 dB	0.002-0.6	0.003-0.9
APC-3.5	$ S_{ij} $	0 to 60 dB	0.003-0.6	0.003-1.0
APC-3.5	$\text{Arg}(S_{ij})$	$0 < S_{ij} < 60$ dB 0 to 360 deg	0.4-10	0.4-10

2. Three-port devices

Connector Type	Quantity	Quantity Range	25-1000 (MHz)
N, APC-7-APC-3.5	$ \text{Coupling} $ (dB)	3-20 dB	0.050 - 0.230
N, APC-7-APC-3.5	$ \text{Mainline} $ (dB)	0 to 8 dB	0.020 - 0.050
N, APC-7-APC-3.5	$ \text{Directivity} $ (dB)	15-25 dB	0.9 - 3.8
N, APC-7-APC-3.5	$ \text{Directivity} $ (dB)	30-40 dB	4 - ∞

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D. Weinschel VM-4B Certification Uncertainties ^{note 2,3,4} on Attenuation

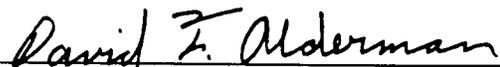
Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			10-2000	2000-8000	8000-12000	12000-18000
N	S _{ij}	0 to 100 dB	0.06-0.60	0.10-1.10	0.25-1.52	0.38-1.80
APC-7	S _{ij}	0 to 100 dB	0.06-0.60	0.10-1.00	0.20-1.43	0.30-1.75
BNC	S _{ij}	0 to 100 dB	0.10-0.90 ^{note 5}	-----	-----	-----

E. Power Ratio Attenuation Expanded Uncertainties ^{note 1,2,3}

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			10-2000	2000-8000	8000-12000	12000-18000
Fixed Attenuators or Step/Variable Attenuators						
N, APC-7	S _{ij}	0 to 11 dB	0.008-0.014	0.014-0.016	0.013-0.015	0.015-0.018
APC-3.5			+ Mismatch Unc.	+ Mismatch Unc.	+ Mismatch Unc.	+ Mismatch Unc.
Isolated Step/Variable Attenuators						
N, APC-7	S _{ij}	0 to 11 dB	0.008-0.014	0.014-0.016	0.013-0.015	0.015-0.018
APC-3.5						

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Group Delay Certification Uncertainties^{note 2,3,4}

<i>Connector Type</i>	<i>Typical Atten. (dB)</i>	<i>Delay (ns)</i>	<i>50-1000 (MHz)</i>
APC-7, N, APC-3.5	0.08	5	0.02 - 0.05
APC-7, N, APC-3.5	0.21	15	0.04 - 0.13
APC-7, N, APC-3.5	0.8	50	0.05 - 0.12
APC-7, N, APC-3.5	3	200	0.15 - 0.41
APC-7, N, APC-3.5	2.2	385	0.46 - 0.50

NVLAP Code: 20/R17

RF/Microwave Power Meters

CW Power Certification Uncertainties^{note 2,3,4}

A. Low to Medium Power CW Microwave Power Meter Calibration at Type N Connector

<i>Quantity</i>	<i>Quantity Range</i>	<i>Frequency (MHz)</i>			
		<i>1 to 2000</i>	<i>2000 to 4000</i>	<i>4000 to 12400</i>	<i>12400 to 16500</i>
Power (dBm)	-30 to -10	.09 to .41 dB	.13 to .41 dB	.14 to .34 dB	.16 to .46 dB
Power (dBm)	-10 to 10	.06 to .27 dB	.10 to .25 dB	.11 to .30 dB	-----
Power (dBm)	10 to 30	.06 to .25 dB	.10 to .21 dB	.11 to .24 dB	-----

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B. Low Power, Wide Range, CW Microwave Power Meter Calibration at Type N Connector

<i>Quantity</i>	<i>Quantity Range</i>	<i>Frequency (MHz)</i>		
		<i>30 to 4000</i>	<i>4000 to 8000</i>	<i>8000 to 12400</i>
Power (dBm)	-60 to -50	0.20 to 0.41 dB	0.25 to 0.43 dB	0.24 to 0.43 dB
Power (dBm)	-50 to -40	0.18 to 0.29 dB	0.23 to 0.35 dB	0.22 to 0.35 dB
Power (dBm)	-40 to -30	0.14 to 0.25 dB	0.16 to 0.32 dB	0.20 to 0.32 dB
Power (dBm)	-30 to -20	0.14 to 0.23 dB	0.16 to 0.27 dB	0.18 to 0.27 dB

C. Medium Power CW Microwave Power Meter Calibration at Type N Connector

<i>Quantity</i>	<i>Quantity Range</i>	<i>Frequency (MHz)</i>		
		<i>12 to 1000</i>	<i>240</i>	<i>2000 to 2500</i>
Power (mW)	1 to 10	1.7 to 3.3%	-----	-----
Power (mW)	1 to 100	-----	-----	3.1 to 4.3%
Power (mW)	80 to 160	-----	1.9 to 2.4%	-----

D. Medium Power CW Microwave Power Meter Calibrations at APC-3.5 Connector

<i>Quantity</i>	<i>Quantity Range</i>	<i>Frequency (MHz)</i>		
		<i>2000 to 4000</i>	<i>4000 to 8000</i>	<i>8000 to 18000</i>
Power (mW)	0.1 to 8	2.8 to 4.0%	3.0 to 4.9%	4.0 to 5.8%

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E. High Power CW Microwave Power Meter Calibrations at Type N Connector

Frequency (MHz)

<i>Quantity</i>	<i>Quantity Range</i>	<i>13.6 to 300</i>	<i>300 to 3000</i>
Power (Watts)	0.2 to 10	9.0 to 9.1%	3.3 to 10.6%
Power (Watts)	10 to 200	4.4 to 10.1%	9.6 to 10.6%

Pulse Power Certification Uncertainties^{note 2,3,4}

A. Pulse Power Meter Calibrations at Type N Connector

<i>Quantity</i>	<i>Quantity Range</i>	<i>2000</i>
Power (mW)	10 to 100	7.3 to 8.2%

THERMODYNAMICS

NVLAP Code: 20/T04
Leak Artifacts

<i>Range</i>	<i>Best Uncertainty (±) in percent^{note 1}</i>	<i>Remarks</i>
Gas Leak - PΔV Technique		
1 x 10 ⁻⁷ moles/s	0.7	Total Gas Measurement
1 x 10 ⁻⁸ moles/s	0.9	Total Gas Measurement
1 x 10 ⁻⁹ moles/s	1.0	Total Gas Measurement

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1 x 10 ⁻¹⁰ moles/s	1.0	Total Gas Measurement
Gas Leak - Accumulate - Dump Technique		
1 x 10 ⁻¹⁰ moles/s to 1 x 10 ⁻¹⁴ moles/s	1.0	1 to 200 Atomic Mass Units for any non- reactive, non-hazardous, non-radioactive gas
Gas Leak - Comparison Technique		
1 x 10 ⁻¹⁰ moles/s	2.5	Helium
1 x 10 ⁻¹¹ moles/s	2.4	Helium
1 x 10 ⁻¹² moles/s	2.3	Helium
1 x 10 ⁻¹³ moles/s	2.3	Helium
1 x 10 ⁻¹⁴ moles/s	7.0	Helium

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THERMODYNAMICS

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Pressure

<i>Range</i>	<i>Best Uncertainty (\pm) in ppm^{note 1}</i>	<i>Remarks</i>
Pneumatic Deadweight Piston Gauges (absolute mode) - Direct Pressure Comparison		
0.2 to 24 psia [\approx 1.4 to 170 kPa]	31	Nitrogen
2.0 to 70 psia [\approx 14 to 480 kPa]	28	Nitrogen
52 to 1000 psia [\approx 0.4 to 7.0 MPa]	46	Nitrogen
Pneumatic Deadweight Piston Gauges (gauge mode) - Direct Pressure Comparison		
0.2 to 24 psig [\approx 1.4 to 170 kPa]	29	Nitrogen
2.0 to 70 psig [\approx 14 to 480 kPa]	26	Nitrogen
52 to 1000 psig [\approx 0.4 to 7.0 MPa]	44	Nitrogen
Hydraulic Deadweight Piston Gauges (gauge mode) - Direct Pressure Comparison		
0.4 to 4.0 kpsig [\approx 2.8 to 28 MPa]	44	Oil
2.0 to 20 kpsig [\approx 14 to 140 MPa]	61	Oil
4.0 to 40 kpsig [\approx 28 to 280 MPa]	59	Oil
Pneumatic Deadweight Piston Gauges - Cross Float (effective area)		
0.2 to 24 psig [\approx 14 kPa to 170 kPa]	35	Nitrogen

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2.0 to 70 psig [\approx 14 kPa to 480 kPa]	33	Nitrogen
52 to 1000 psig [\approx 0.4 MPa to 7.0 MPa]	46	Nitrogen
Hydraulic Deadweight Piston Gauges - Cross Float (effective area)		
0.4 to 4.0 kpsig [\approx 2.8 to 28 MPa]	46	Oil
2.0 to 20 kpsig [\approx 14 to 140 MPa]	67	Oil
4.0 to 40 kpsig [\approx 28 to 280 MPa]	61	Oil

Secondary Pressure Low Range Absolute

<i>Pressure</i>	<i>Best Uncertainty (\pm) in psia^{note 1}</i>	<i>Remarks</i>
0.2 psia [\approx 1.4 kPa]	0.0013	Nitrogen
1.0 psia [\approx 7.0 kPa]	0.0013	Nitrogen
6.0 psia [\approx 41 kPa]	0.0017	Nitrogen
10 psia [\approx 70 kPa]	0.0021	Nitrogen
15 psia [\approx 100 kPa]	0.0028	Nitrogen

Secondary Pressure Low Range Gauge or Absolute

<i>Pressure</i>	<i>Best Uncertainty (\pm) in psi^{note 1}</i>	<i>Remarks</i>
20 psi [\approx 140 kPa]	0.009	Nitrogen
40 psi [\approx 280 kPa]	0.010	Nitrogen

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60 psi [\approx 410 kPa]	0.011	Nitrogen
80 psi [\approx 550 kPa]	0.013	Nitrogen
100 psi [\approx 690 kPa]	0.014	Nitrogen
Secondary Pressure Mid-Range Gauge or Absolute		
<i>Pressure</i>	<i>Best Uncertainty (\pm) in psi^{note 1}</i>	<i>Remarks</i>
200 psi [\approx 1.4 MPa]	0.137	Nitrogen
500 psi [\approx 3.4 MPa]	0.157	Nitrogen
1.0 kpsi [\approx 7.0 MPa]	0.201	Nitrogen
1.5 kpsi [\approx 10 MPa]	0.247	Nitrogen
2.0 kpsi [\approx 14 MPa]	0.280	Nitrogen
Secondary Pressure High-Range Gauge or Absolute		
4.0 kpsi [\approx 28 MPa]	0.6	Nitrogen
6.0 kpsi [\approx 41 MPa]	0.8	Nitrogen
8.0 kpsi [\approx 55 MPa]	1.0	Nitrogen
10 kpsi [\approx 70 MPa]	1.0	Nitrogen

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THERMODYNAMICS

NVLAP Code: 20/T07

Resistance Thermometry

<i>Temperature (°C)</i>	<i>Best Uncertainty (±) in m °C^{note 1}</i>	<i>Material/ Equilibrium State</i>
-189.3442	0.53	Ar/Triple Point
-38.8344	0.30	Hg/Triple Point
0.01	0.16	H ₂ O/Triple Point
29.7646	0.12	Ga/Melting Point
156.5985	2.00	In/Freezing Point
231.928	0.92	Sn/Freezing Point
419.527	1.10	Zn/Freezing Point
660.323	5.0	Al/Freezing Point
961.78	10.0	Ag/Freezing Point

Standard Platinum Resistance Thermometer Calibrations

-189.3442	1.1	Ar/Triple Point
-38.8344	0.6	Hg/Triple Point
0.01	0.6	H ₂ O/Triple Point

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29.7646	0.6	Ga/Melting Point
156.5985	2.6	In/Freezing Point
231.928	1.8	Sn/Freezing Point
419.527	2.0	Zn/Freezing Point
660.323	5.2	Al/Freezing Point
961.78	10.1	Ag/Freezing Point

Comparison Calibrations

<i>Temperature Range (°C)</i>	<i>Best Uncertainty (±) in °C^{note 1}</i>	<i>Type of Device</i>
-80 to 0	0.10	Thermocouples
10 to 150	0.10	Thermocouples
150 to 660	0.22	Thermocouples
660 to 700	0.47	Thermocouples
700 to 1100	2.5	Thermocouples
1100 to 1300	2.8	Thermocouples
-80 to 0	0.06	RTD/IPRT/PRT
10 to 150	0.09	RTD/IPRT/PRT
150 to 660	0.21	RTD/IPRT/PRT

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-80 to 0	0.05	Liquid in Glass
10 to 150	0.06	Liquid in Glass
-80 to 0	0.06	Thermistors
10 to 150	0.09	Thermistors
150 to 250	0.21	Thermistors

Thermocouple Simulator/Readout Calibration Methods

Type	ITS-90 Temperature Range (°C)	Best Uncertainty (\pm) in °C ^{note 1,9}	NIST Monograph 175 Reference Table ^{note 10}
K	-200 TO 1370	0.10 to 0.30	7.3.3
J	-200 to 1200	0.08 to 0.22	6.3.3
E	-240 to 1000	0.07 to 0.38	5.3.3
T	-240 to 400	0.09 to 0.53	9.3.3
R	-50 to 1750	0.38 to 1.09	3.3.3
S	-50 to 1750	0.43 to 1.02	4.3.3
B	100 to 1750	0.43 to 4.45	2.3.3
C	0 to 2300	0.24 to 0.82	

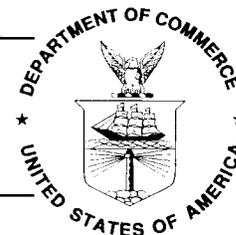
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THERMODYNAMICS

NVLAP Code: 20/T10

Vacuum

<i>Range</i>	<i>Best Uncertainty (\pm) in percent^{note 1}</i>	<i>Remarks</i>
Ionization Gage Reference for direct comparison		
1.3 x 10 ⁻⁶ Pa < reading \leq 1.3 x 10 ⁻⁵ Pa	4.8	N ₂ ; 10 ⁻⁸ Torr
1.3 x 10 ⁻⁵ Pa < reading \leq 1.3 x 10 ⁻⁴ Pa	4.7	N ₂ ; 10 ⁻⁷ Torr
1.3 x 10 ⁻⁴ Pa < reading \leq 1.3 x 10 ⁻³ Pa	4.7 - 2.5	N ₂ ; 10 ⁻⁶ Torr
Spinning Rotor Gage Reference for direct comparison		
1.3 x 10 ⁻⁴ Pa < reading \leq 1.3 x 10 ⁻³ Pa	4.3 - 2-1	N ₂ ; 10 ⁻⁶ Torr
1.3 x 10 ⁻³ Pa < reading \leq 1.3 Pa	2.1	N ₂ ; 10 ⁻⁵ Torr - 10 ⁻³ Torr
1.3 Pa \leq reading \leq 13 Pa	2.2	N ₂ ; 10 ⁻³ Torr

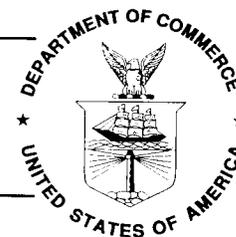
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Capacitance Diaphragm Gages Reference for direct comparison

1.3 x 10 ⁻¹ Pa ≤ reading ≤ 13.3 Pa	2.1 - 0.7	N ₂ ; 0.1 Torr range
13.3 Pa ≤ reading ≤ 133.3 Pa	0.7	N ₂ ; 1 Torr range
133.3 Pa ≤ reading ≤ 1.3 kPa	0.4	N ₂ ; 10 Torr range
1.3 kPa ≤ reading ≤ 13.3 kPa	0.2	N ₂ ; 100 Torr range
13.3 kPa ≤ reading ≤ 133.3 kPa	0.6 to 0.1	N ₂ ; 1000 Torr range

Secondary Capacitance Diaphragm Gages Reference for direct comparison

1.3 x 10 ⁻¹ Pa ≤ reading ≤ 13.3 Pa	2.2 to 0.9	N ₂ ; 0.1 Torr range
13.3 Pa ≤ reading ≤ 133.3 Pa	1.1	N ₂ ; 1 Torr range
133.3 Pa ≤ reading ≤ 1.3 kPa	0.5	N ₂ ; 10 Torr range
1.3 kPa ≤ reading ≤ 13.3 kPa	0.5	N ₂ ; 100 Torr range
13.3 kPa ≤ reading ≤ 133.3 kPa	0.59 to 0.11	N ₂ ; 1000 Torr range

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1. Expanded uncertainty with coverage factor of $k=2$, unless otherwise specified.
2. Approximate value. Actual value determined by test results.
3. The uncertainty ranges are the lowest and highest uncertainty values within the specified frequency range and quantity range.
4. Uncertainty consists of an appropriate combination of the measurement uncertainty (which includes all significant sources of uncertainty associated with the calibration process) and uncertainties due to use, environment, handling or variation with time over the certification interval.
5. Maximum frequency for BNC is 1000 MHz.
6. ASTM loading range classes (e.g., A, AA) are not used or reported.
7. Calibrations to 30,000 lbf versus load cells can be automated; other calibrations are manual.
8. Uncertainties listed are linearized forms ($A' + B'L$) of uncertainties calculated as root sum squares of constant and length-dependent terms $\{A^2 + (BL)^2\}^{1/2}$. A' and B' are calculated by fitting a straight line through the RSS uncertainty values at the upper and lower limits of range.
9. Uncertainty is dependent on the specific temperature point tested.
10. Referenced tables in NIST Monograph 175 (April, 1993) provide values for emf E output/input of the thermocouple simulator/readout and the Seebeck coefficient S for the specific temperature points within the specified ranges. The best uncertainty (at $k=2$) of the emf E in μV is equal to the product of $U * S$, where U is the best uncertainty (at $k=2$) of the temperature point tested.

December 31, 2001

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David F. Alderman

For the National Institute of Standards and Technology